FACTSHEET

AGRICULTURAL ENGINEERING

ORDER NO. 06-007

JANUARY 2006

AGDEX 717

Ontario Ministry of Agriculture, Food and Rural Affairs

ENERGY EFFICIENT DAIRY LIGHTING

S. Clarke, P. Eng. and H. House, P. Eng.

LIGHTING BASICS

Lighting plays a large role in dairy production performance. It is possible to reduce energy costs by making small changes to the lighting on your dairy operation. A well designed, energy efficient lighting system can mean higher lighting levels, better livestock performance and lower energy costs.

This Factsheet offers suggestions on how to change your lighting system to reduce energy costs by 15%–75%. It highlights different lighting systems such as incandescent, fluorescent, compact fluorescent, fluorescent tube lighting, high intensity discharge and Light Emitting Diode (LED). An example of the cost to change from an incandescent to a fluorescent light system is also included.

LIGHT LEVELS

To know how to reduce energy costs it is important to understand the terms used to measure light.

- **Lumens** – light output from a lamp is measured in the term "lumens" (lm). For example, a 40 watt (W) incandescent light bulb produces about 13 lumens per watt or 13 lm/W.
- **Lux or Foot-Candle** – the light level at the working surface is measured in lux or foot-candle (fc). [10 lux equals ≈1 fc] Typical light levels in animal pens and corner areas of barns can be less than 5 lux or ½ fc. Outside on a bright sunny day in mid summer the light level will be around 80,000 lux or 8,000 fc.
- **Average Rated Life** – the average time it takes for 50% of light bulbs to fail.
- **Colour Rendering Indexes** (CRI) – the measurement of the light sources ability to render colours the same way sunlight does.

When considering ways to reduce energy costs think about how to get the most light output per lamp size (lm/W). Typical lumen outputs are shown in Table 1 and *Figure 1* along with other light system information.

TABLE 1. General Characteristics of Light Sources Used for Indoor Lighting of Livestock and Poultry Facilities

Lamp Type	Lamp Size (W)	CRI	Efficiency (Ballast losses not included) (Lumens/ W)	Typical Lamp Life (hr)
Incandescent	25–200	100	11-20	750-5,000
Halogen	50–150	100	18-25	2,000-3000
Fluorescent T8 (4 ft)	32	75	88	20,000 (24,000 for low mercury premium lamps)
Fluorescent T5 (4 ft)	28	85	104	20,000
Fluorescent T5HO (4 ft)	54	85	93	20,000
Compact Fluorescent	5–57	80–90	50-80	10,000
Metal Halide	35–70 400	60–80	60-94	7500-10,000 20,000 (higher wattages, longer life)
High Pressure Sodium	35–400	20–80	63-125	15,000-24,000
Light Emitting Diode	1.2–1.4	70–90	16-53	60,000-100,000 White is lower

Note: CRI means colour-rendering index. Fluorescent T12 (1.2 m or 4 ft) has not been included as they are not recommended. This is because: 1) they are not as energy efficient as T8 or T5; and 2) complete fixtures and replacement components will be unavailable over the next few years

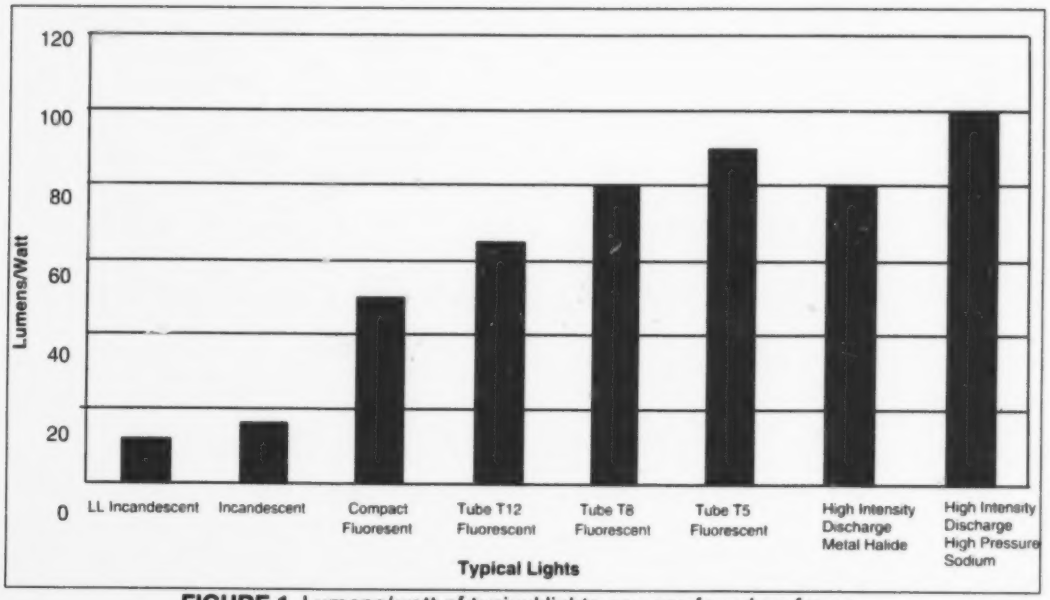

FIGURE 1. Lumens/watt of typical lights sources found on farms.

FIGURE 2. Low cost incandescent systems have high maintenance and operating costs. Note the dirty build-up on a long-life lamp.

LIGHT TYPES

Incandescent

With today's relatively high light-level requirements in barns and with lights on for longer periods, the old Edison style incandescent lamps are only about 5% efficient at converting energy to light. The rest is wasted as heat energy. Incandescent lights also attract flies and other insects, and are quickly coated with dirt that further reduces the amount of light available. *Figure 2* shows examples of incandescent lights and the dirt problem. Incandescent lights also have a relatively short-rated life compared to other lighting types (see Table 1). For example, a 100 W, 1,000 hr (standard rated lamp) could be expected to last 63 days at 16 hr/day. Installing 'long life' lamps with a rated life of 5,000 hr, the bulb would last 312 days, but the actual light output is reduced by about 25% over the regular 1,000-hr lamp.

Fluorescent

Fluorescent light should be the main light source in dairy production. Fluorescent light is very energy efficient compared to incandescent, has long life cycles (when correct fixtures are installed and adequate maintenance) and can provide good light quality for livestock.

A few reasons to switch to fluorescent lighting from incandescent are listed here.

- Fluorescent lighting takes less energy to provide the desired level of light.

- Fluorescent tube lamps last 20,000 hr and cost about $2.00 each; incandescent lamps cost as little as $0.50/each and last from 1,000 (regular life) to 5,000 (long life) hours (anything over 2,000 hr is considered long life).

- Conversion from incandescent to fluorescent will reduce energy usage by up to 75%.

- Fluorescent typically has a payback time of less than 2 years. In some cases payback can be as soon as 4 months.

TYPES OF FLORESCENT SYSTEMS

There are 2 types of fluorescent systems used on farms: **compact** and **tube fluorescents.**

Compact Fluorescent

Compact fluorescent (CF) lighting systems provide good energy efficiency and can easily replace incandescent fixtures. There are 2 main types: *electronic ballast* and *electromagnetic.* (See *Figure 3.*)

- Electronic ballast systems have a rated life of 10,000 hr.

- Electromagnetic units have a detachable lamp from the ballast. Lamps are rated at a life of 10,000 hr, ballasts at 40,000 hr. Generally, compacts are a good, low cost retrofit.

- Compact fluorescent bulbs for barns need to be rated or approved for damp locations.

- Purchase compact fluorescent bulbs rated "Energy Star" for the best quality and light output.

To see which size CF to install, determine the lumen output of the current incandescent lights and then match this value with the CF lumen output. See Table 2.

TABLE 2. Light Output of Compact Fluorescent compared to Incandescent Bulbs (in Lumens)

Incandescent Light Bulbs		Compact Fluorescent Light Bulbs	
Watts	Lumens	Watts	Lumens
25	270	5	250
40	510	7	400
52	780	9	600
60	860	15	900
90	1,540	18	1,250
100	1,680	26	1,800

Source: hydroonenetworks.com/en/efficiency/downloads/PowerSaver_02_Lighting.pdf

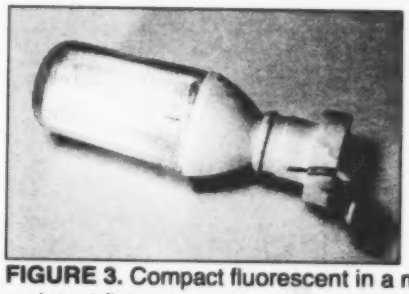

FIGURE 3. Compact fluorescent in a moisture resistant fixture. (Source: Agviro, Inc.)

To date there has only been limited success with dimming compact fluorescents, however future research will likely solve the reliability issue. Only CF systems labelled "dimmable" can be used when dimming. **CF lights are a very good choice in dairy barns when low levels of light are required.** However, if dimming is required, a mix of incandescent with CFs may be a good solution. (See *Figure 5*)

When considering retrofitting a lighting system bear in mind that CF lamps have shorter equipment life and higher replacement costs compared to T8 (standard 4 ft) fluorescent tube systems. See the section below on fluorescent tube lighting for details.

Fluorescent Tube Lighting

Fluorescent tubes come in a variety of lengths and diameters. Typically farms use 4-foot lengths (1.2m). Tube diameter is measured in eighths of an inch. T12s (1.5 in.) — the old standard— are being replaced by T8 (1 in.) and T5 (0.6 in.) systems (see *Figure 4*). (These are the standard industry sizes.)

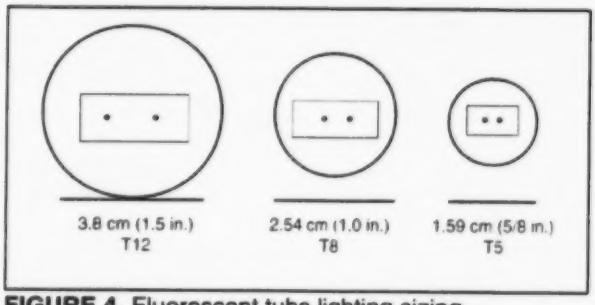

FIGURE 4. Fluorescent tube lighting sizing.

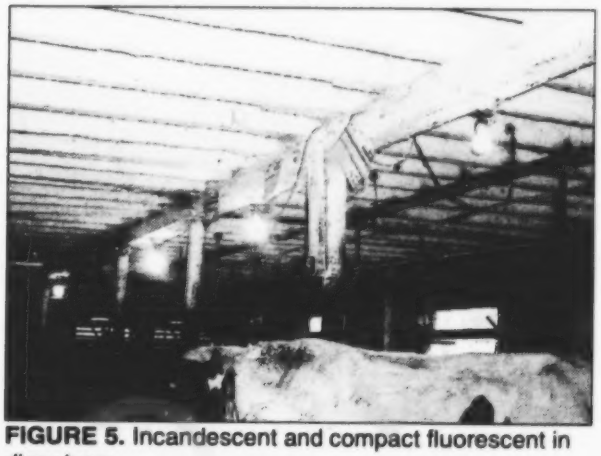

FIGURE 5. Incandescent and compact fluorescent in diary barn.

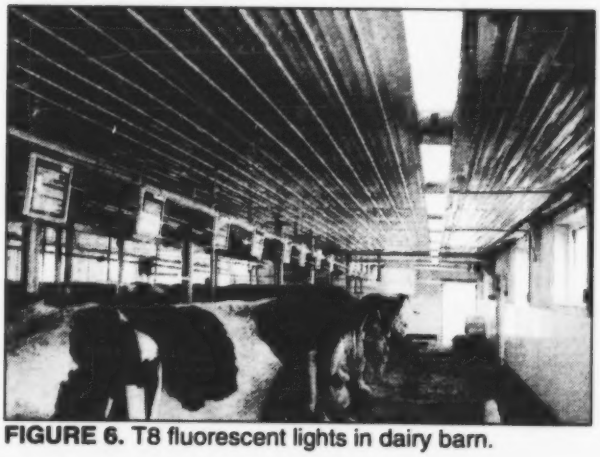

FIGURE 6. T8 fluorescent lights in dairy barn.

For barns where the ceiling height is less than 3.7 m (12 ft) the new recommendation is the T8 fluorescent fixture with electromagnetic ballast, mounted in weatherproof fibreglass or plastic housing with a continuous gasket between the lens and fixture. Also it is important to ensure the fixture uses 8 clips to hold the lens on so there is less chance of barn air getting into the fixture. These units are typically:

- 4 times more efficient than regular incandescent lights
- up to 30% more efficient than T12 fluorescent tubes
- last at least 20 times longer than regular life incandescent lamps. (See *Figure 6*)

T8 fluorescents are an ideal energy efficient alternative to incandescent, compact fluorescent and T12 fluorescent systems. T5 fluorescent tube systems are shorter than T12 or T8. They produce more light, have better colour rendition (more true light), a higher efficiency and more dimming options available. They maintain their light level better than T12 and most T8 systems. They provide 95% of their original light output after 40% (8,000 hr) of their average life. **T5 lamps are not recommended for use in vapour-tight fixtures due to heat build up; therefore, their use on farms will be limited to clean, dry environments.** However future research will likely solve the over heating and reliability issue of T5.

Dimmable fluorescent tube lights are currently being tested in several commercial turkey grower facilities in Ontario. The advantage of a dimming system is the ability to simulate dawn and dusk periods by slowly raising and/or lowering light levels.

Photocells controllers can be used with fluorescent lights in barns with windows and curtains. The photocell controller can dim or turn off lights near sidewalls during the day when natural light levels are sufficient. This process is called Day Lighting and can save even more energy and money

HIGH INTENSITY DISCHARGE (HID)

Where barn ceilings are more than 3.7 m-high (12 ft-high), for example, dairy free stall barns and machinery sheds. consider more efficient high intensity discharge (HID) fixtures, including metal halide (MH) and high pressure sodium (HPS). They are easy to install and maintain and require fewer fixtures to provide the same level of light. See *Figures 7* and *8*.

Metal halide fixtures can be operated on either a regular or pulse start ballast. A pulse start ballast will save about 12.5% or 50 W on a 400 W metal halide fixture.

FIGURE 7. Metal halide fixtures.

FIGURE 8. High pressure sodium fixtures (the light is yellow. (Source: Agviro, Inc.)

LIGHT EMITTING DIODE (LED)

Light Emitting Diode or LED systems are not yet used in livestock and poultry production facilities. Research is required to ensure this technology will fit with agricultural applications. Energy efficiency of LED lamps can be very high (50 lumens/W) and life is much longer (up to 100,000 hr) than other light systems. If the technology can be adapted for barn environments, it is expected that LED lighting systems will provide large on-farm energy savings in the future.

LEDs come in various forms — spot, linear or strip (see *Figure 9*) and monochromatic colours. They can be dimmed.

FIGURE 9. LED strip lighting. (Source: GVA Lighting Inc.)

The advantages of LEDs include:

- environmental friendly–energy efficient with 1/5th of the power consumption of incandescent lamps. LEDs contain no mercury and since they last longer there is less waste
- long life - LEDs lasts up to 100,000 hr compared to the typical incandescent bulbs at 1,000 hr or 20,000 hr fluorescent lamps
- low maintenance cost
- miniaturization - small size allows them to be used in areas not easily accessible
- high reliability - LEDs are solid-state devices, without moving parts, glass or filament to break. They are robust and vibration proof
- directed light for increased system efficiency
- fully dimmable
- multicolour - available in all colours
- high speed response - immediate response, no preheat or starting time required.

TIMING AND MOTION SENSORS

Other considerations for energy efficient lighting systems include the use of timers, programmed to turn lights on/off to meet daily livestock needs and motion sensors in personnel areas such as hallways and entranceways.

Recent innovations include:

- A controller that will gradually turn light intensity up and down to simulate the sun. These controllers allow an operator to do this many times in a day.

- A controller that uses a photocell to change the light intensity as required from each row of lights. This is useful where a barn has translucent sidewall openings and can thus use the natural light as required and save substantial energy.

DAIRY OPERATION – ENERGY EFFICIENCY OPPORTUNITIES

Incandescent lights operating for extended periods of time can be replaced with more energy efficient types of light systems. The type of system will depend on a number of factors including:

- room temperature
- mounting height from floor to ceiling
- size of area to be lit
- payback period.

Some energy efficient lighting systems, such as compact fluorescent and tube fluorescent, either do not start or operate poorly in cold temperatures unless cold start ballasts are installed.

Lights that operate daily for long durations, year-round will have faster paybacks than lights that are only turned on briefly. The quicker the payback, the more appealing a lighting system will be for most farm owners and managers.

An easy way to switch to a more energy efficient lighting system is to replace incandescent bulbs with compact fluorescent (CF) lamps and ballasts of equivalent light output. The compact fluorescent system can be screwed into the existing socket. No rewiring is involved. The average cost of a CF is $4-$15 per light depending on the wattage. A CF has a rated life of 10,000 hr. Other energy efficient lighting systems require more effort. Installing fluorescent tubes or HID systems requires rewiring and a lighting design to ensure that the area is evenly lit at the right light intensity.

CFs come in a range of power ratings, from 5–28 W in screw-in versions and up to 55 W in hardwired models. As a rough guide, a 3:1 ratio, incandescent to CF wattage, provides the same light output.

Incandescent lamps may be economical where lights are only turned on occasionally, such as in storage rooms.

HID lamps have some advantages over CFs, including higher output and less sensitivity to starting and operating temperatures. However, they take a long time to warm up and relight if shut off; they offer fewer colour temperature choices, provide poorer colour rendering, and some units flicker at a frequency of 120 Hz. The newest metal halide lamps being introduced may solve some of these problems. HID systems are well suited to areas such as free stall or loose housing barns and some parlours with high ceiling heights.

The minimum light intensities required for various tasks or in different work areas of a dairy operation are listed in Table 3.

Long-Day Lighting

During winter, cows respond to the shorter daylight hours by reducing feed consumption. When they eat less food, they produce less milk. Long-day lighting (16-18 hr. of daylight) increases milk production by simulating summer conditions. Studies show that long-day lighting can boost milk production from 5%-16%.

Photocells can be used with most light systems. They are well suited for use in free stall, loose housing, tie stall and parlour areas. Photocells provide even greater benefits when working on a dimmable light system (such as some tube fluorescents). Photocells can sense the amount of light present in a space. They send the light level information back to a controller, which has been programmed to maintain the light at a given level (in lux or foot-candles). When natural light levels fall below this preset limit, the controller sends a signal to the lighting system and the lights turn on. The lights may come on at full brightness if a dimming controller does not operate them or they might come on just enough to maintain the light level at the preset limit with a dimming controller. When a dimming controller is used, the lights will become brighter and brighter as the amount of natural daylight declines until the preset limit is reached.

In areas requiring high-pressure washing, waterproof fixtures are necessary to prevent moisture from getting into the fixture.

Table 3 below summarizes the light intensity recommended at each section of dairy farm to optimize production from cows, to minimize cost, and maximize energy efficiency.

SYSTEM COSTS FOR RETROFIT AND NEW INSTALLATIONS

The cost to install and operate an incandescent light system in a dairy barn with 10–100 W long life lamps in each of 3 rows was compared to the cost of a fluorescent single tube system. See *Table 4* below. The calculations assume an energy cost of $0.0953/kWh (March 2005 rate) and that the lights are typically running an average of 18 hr per day. Each 100 W long-life incandescent lamp will provide just over 1,200 lumens. This system would cost about $450 to install and $1,918 annually to operate. Installing 20, 4-ft single tube, T8 fluorescent fixtures would provide an increased light level (by as much as 44%). This T8 system would cost $2,400 to install and only $511/yr to operate. So over a 2-yr period

you could save more than $800 by switching to a T8 fluorescent lighting system from an incandescent one.

TABLE 3. Recommended Illumination Levels for Dairy Livestock Facilities

Work Area or Task	Minimum Light Intensity in Lux [Foot-Candles]
Parlour, pit and near udder	500 [50]
Parlour, stalls & return lanes	200 [20]
Parlour, holding area	100 [10]
Milk room, general	200 [20]
Milk room, washing	750-100 [75-100]
Tie stall barn, manger alley	100 [10]
Tie stall barn, milking alley	250-300 [25–30]
Free stall barn, feed alley	200 [20]
Free stall barn, stall area	108 [10]

(Source: ASAE, 1993; NFEC, 1993; MWPS, 1992; Leech and Person, 1993)

TABLE 4. Summary of New Installations System Costs to Switch from Incandescent to Fluorescent Lighting System

	Incandescent 100 watt	T8 Fluorescent Fixtures
Number of fixtures	30	20
Install cost	$450.00	$2,400.00
Cost to operate for 2 yr	$1,918 x 2 = $3,836	$511 x 2 = $1,022
Total cost over 2 yr	$4,286	$3,422
Savings over 2 yr		$800

For a retrofit, with 100% of the capital to be paid with savings, the simple payback is 1.7 years. For a new facility, where the original cost for the incandescent system is deducted from the total fluorescent capital cost, the payback is an even faster: 1.4 years.

SUMMARY

Over the long run, lighting on dairy farms has the potential to save energy for the farmer. One simple way to reduce energy costs by 75% is to switch from incandescent lighting to fluorescent T8 lighting. Using dimmers can also reduce energy costs. By making these changes, along with other improvements, your dairy operation lighting system will be more energy efficient. This can lead to improved farm productivity and increased revenue, while lowering energy costs.

This Factsheet was written by **Steve Clarke**, P.Eng., Energy and Crop Systems Engineer, and Harold House, P. Eng., Dairy and Beef Housing and Equipment Engineer, Environmental Policy and Programs Branch, OMAFRA. It was peer reviewed by **Elin Gwyn**, Marketing and Communications Officer, Environmental Policy and Programs Branch, OMAFRA

Agricultural Information Contact Centre
1-877-424-1300
ag.info@omafra.gov.on.ca

www.omafra.gov.on.ca

POD
ISSN 1198-712X
Également disponible en français
(commande n° 06-008)